A SIMPLE MODEL OF THE ISO 9705 IGNITION SOURCE

Marc L. Janssens, Southwest Research Institute

ISO 9705 Room Test Standard--In 1993, the International Organization for Standardization published ISO 9705, "Full-Scale Room Test." The apparatus described in this standard consists of a room (3.6 m deep by 2.4 m wide by 2.4 m high), with a single ventilation opening (0.8 m wide by 2 m high) in the front narrow wall. Several walls or the ceiling or both are covered with a combustible lining material that is exposed to a (gas burner) ignition source. The primary measurements are temperature and total heat flux at various locations inside the room, heat and smoke release rate from the fire, and time to flashover. Two ignition burners are described in the standard: the Nordic burner developed in Sweden, and the ASTM burner commonly used in North America. The former is 0.17 m wide, the latter is 0.3 m wide. Both have a square surface that is 0.3 m above the floor of the room. The Nordic burner is operated at a heat release rate of 100 kW for 10 minutes, followed by 300 kW for another 10 minutes. The ASTM burner is operated at 40 kW for 5 minutes, followed by 160 kW for 10 minutes.

Modeling of the ISO 9705 Room Test--The rather high cost of full-scale fire experiments triggered the development of simple computer models that can be used as an alternative to the test. The most complete model was developed by Quintiere.[1] This model assumes that the ignition burner flame exposes a rectangular area of the back and side walls in contact with the burner to a uniform heat flux, $\dot{q}''_{ig}$. The width of the area $x_{p,0}$ (m), is equal to the burner width W_b (m). The height of the area $y_{p,0}$ (m), is closely related to the burner flame height L_f (m). For the model calculations reported by Quintiere et al.,[1,2,3] values for $y_{p,0}$ and $\dot{q}''_{ig}$ were chosen in qualitative agreement with some experimental data. The objective of this paper is to develop a systematic procedure for calculating the burner geometry and heat flux characteristics.

Geometry--As far as the geometry of the heated area is concerned, the suggested approach is to determine $y_{p,0}$ so that the surface area of the rectangle on the right in Figure 1 is equal to that of a more realistic shape of the heated region, as shown on the left in Figure 1. The latter is characterized by the flame height, L_f, and by the width of the flame at half-height, $W_{1/2}$. Janssens and Tran obtained the following correlation for L_f based on measurements for the ASTM burner[4]

$$L_f = 2.9D(\dot{Q}*)^{2/3}$$

In order to determine $W_{1/2}$, a criterion is needed to define the flame boundary. Janssens and Tran published Gaussian temperature profiles at various heights for the ASTM burner[4]. Their data indicate that 600°C is a suitable temperature to describe the flame boundary. Therefore, $W_{1/2}$ is estimated as the lateral distance from the corner at half the flame height where the temperature is equal to 600°C. Temperature profiles measured by Kokkala are used to determine $W_{1/2}$ for the Nordic burner.[5] Finally, the equivalent area approach is used to determine $y_{p,0}$ as follows

$$A_f = \frac{W_{1/2}L_f}{2} + \frac{W_b L_f}{4} \equiv W_b y_{p,0}$$

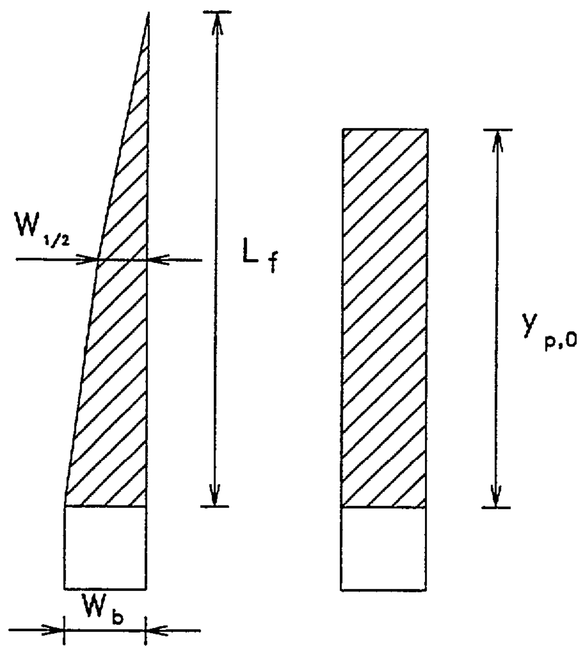

Figure 1. Equivalent heated area

The results of the calculated equivalent geometry are shown in Table 1.

Flame Heat Flux--The second step is to estimate the heat flux from the burner flame. The flux consists of a radiative and a convective part:

$$\dot{q}''_{ig,net} = \dot{q}''_{ig,r} - \epsilon\sigma T_s^4 + h_c(T_f - T_s)$$

Quintiere's model calculates T_s using Duhamel's superposition integral. To determine the incident radiative heat flux, it is assumed that a certain fraction, χ_r, of $\dot{Q}_{ig}$ is lost by radiation. McCaffrey measured χ_r for propane as a function of the Froude number, Fr.[6] His data indicate that for the range of Fr corresponding to the Nordic and ASTM burner, χ_r varies between 0.31 and 0.33. Tewarson gives χ=0.95 for the combustion efficiency of propane.[7] Assuming that half of the radiation strikes the walls, the radiative burner flame flux follows from

$$\dot{q}''_{ig,r} = \frac{\chi \chi_r \dot{Q}_{ig}}{4 y_{p,0} W_b} .$$

Estimating the convective part is more difficult because it depends on the bulk temperature and velocity of the fluid, and surface temperature of the wall. The average flame temperature over the full width at half the flame height, based on the measurements by Janssens and Tran, is equal to T_f=754 °C. Velocity distributions measured by Janssens and Tran are used to determine an average value of the upward velocity at half the flame height. Hasemi and Tokunaga found that the centerline velocity for diffusion gas burners is proportional to the square root of the product of the centerline temperature rise above ambient and the height above the burner surface.[8] This relationship is used to determine velocities for the Nordic burner. Finally, assuming a constant wall temperature of 55°C (typical temperature for cooling water of heat flux meters), property data for air and the standard convective heat transfer correlations for forced flow over a flat plate are used to estimate convective heat transfer. The calculated values for the convection coefficient are given in Table 1. The resulting values for the total flame flux based on a 55°C wall temperature are in the range of 30-47 kW/m^2. This is significantly lower than the value of 60 kW/m^2 used by Quintiere.

Table 1. ISO 9705 Ignition Source Geometry and Heat Transfer Characteristics

Burner type	W_b (m)	$\dot{Q}_{ig}$ (kW)	L_f (m)	$W_{1/2}$ (m)	$y_{p,0}$ (m)	$\dot{q}''_{ig,r}$ (kW/m^2)	h_c (W/m^{2}K)
Nordic	0.17	100	1.96	0.14	3.73	35	14
Nordic	0.17	300	4.00	0.23	1.29	36	16
ASTM	0.30	40	0.70	0.14	0.45	22	11
ASTM	0.30	160	1.79	0.18	1.37	30	13

Validation--Predictions for six materials and two ISO 9705 room test scenarios, one involving the ASTM burner and one with the Nordic ignition source, were presented earlier.[9] Calculated flashover times are in reasonable agreement with the measurements, indicating that the simple model for the ignition source is probably acceptable for engineering analyses. Additional comparisons are needed to confirm this conclusion.

REFERENCES

1. J. Quintiere, *Fire Safety Journal,* Vol 20, 1993, pp. 313-339.
2. J. Quintiere, G. Haynes & B. Rhodes, *Journal of Fire Protection Engineering*, Vol 7, 1993, pp. 1-13.
3. J. Quintiere, M. Hopkins & D. Hopkins, *ICFRE*, SFPE, Boston, MA, 1995, pp. 272-277.
4. H. Tran & M. Janssens, *Journal of Fire Protection Engineering*, Vol 5, 1993, pp. 53-66.
5. M. Kokkala, *Interflam '93*, Interscience Communications, London, UK, 1993, pp. 13-24.
6. B. McCaffrey, Combustion Institute, Western States Section, Paper No. 81-15, 1979.
7. A. Tewarson, *SFPE Handbook of Fire Protection Engineering*, SFPE, Boston, MA, 1995, pp. 3-53 to 3-115.
8. Y. Hasemi & T. Tokunaga, *Combustion Science & Technology*, Vol 40, 1984, pp. 1-17.
9. M. Janssens et al., *Fourth Fire & Materials Conference*, Interscience Communications, London, UK, 1995.